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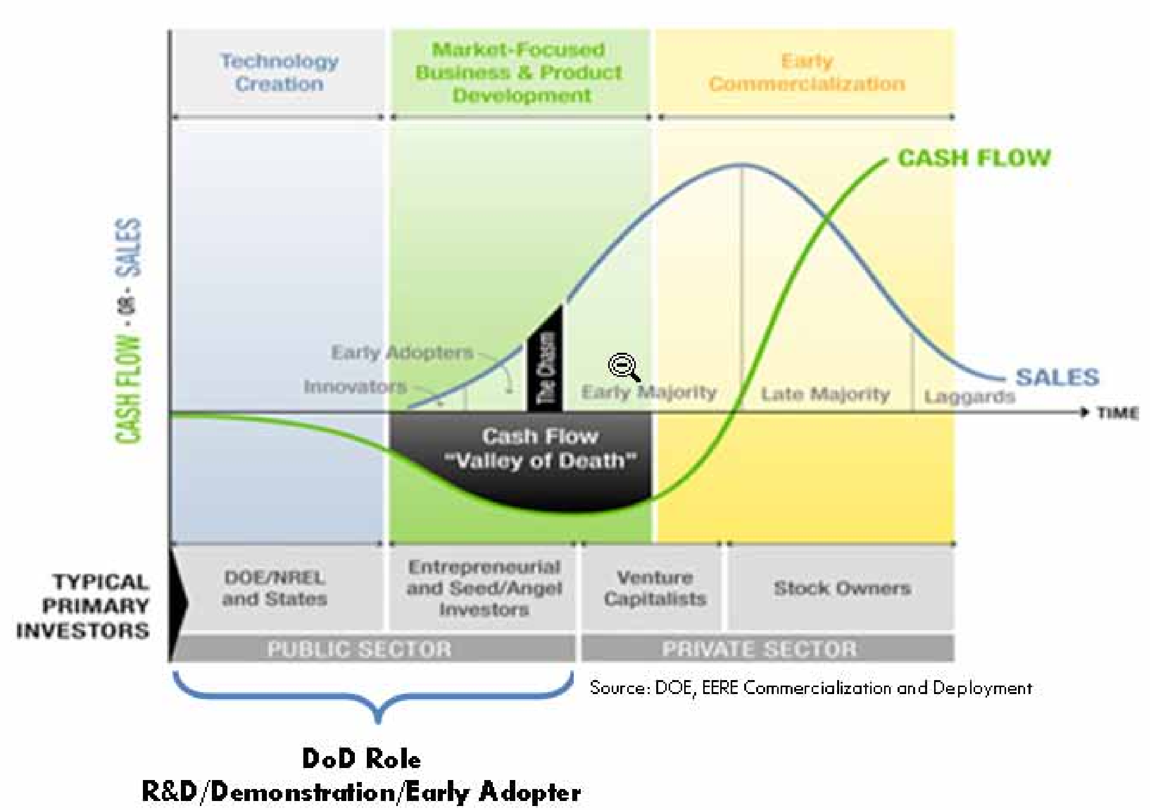
Bridging the Gap: The Role of DOD in Clean Energy Commercialization

DOD Installations as “Living Laboratories”

Harold Sanborn, René Parker, and Erik Kallio

August 2010



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Bridging the Gap: The Role of DOD in Clean Energy Commercialization

DOD Installations as "Living Laboratories"

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Final Report

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Abstract: The Department of Defense (DOD) has a unique opportunity to be a leader in bridging the gap between research and development (R&D) and commercial clean energy technologies. Faced with the inextricable linkage between energy, security, environment, and economics, the DOD is positioned to play an important role in the demonstration of new and emerging clean energy technologies, and also to become early first adopters of the technologies. Military installations are “living laboratories”; they offer a controlled and safe environment to demonstrate emerging technologies and to provide a critical feedback loop between the end-users and technology providers. This work reviewed Federal energy policy, explored the role of R&D in meeting DOD needs with regard to energy issues, defined measures of “Technology Readiness and Commercialization, outlined the role of installations as “living laboratories,” and provided several case studies of energy-related studies done at Army installations.

Executive Summary

The rising cost of energy, diminishing access to fossil fuel resources, dependence on foreign oil, and increased greenhouse gas emissions all pose a threat to national security, the economy, and the environment. As a result, the U.S. government is taking steps to find innovative solutions to these problems while implementing low cost, commercial technologies to address near term challenges. To supplement this renewed emphasis on government research and development (R&D) and increase in government R&D investment, there is a need for greater coordination among Federal agencies, and demonstrations and significant first buys by the government to "jump start" key markets. R&D is vital to the discovery of innovative solutions. The U.S. government, particularly the U.S. Department of Defense (DOD), is uniquely positioned to lead this effort. As the single largest Federal user of energy, the DOD is especially sensitive to the increasing security risks associated with a vulnerable electrical grid and dependence on foreign oil.

The DOD has a unique opportunity to lead in bridging the gap between clean energy R&D and the resulting commercial technologies. Faced with the inextricable linkage between energy, security, environment, and economics, the DOD is positioned to play an important role not only in demonstrating new and emerging clean energy technologies, but also in becoming early first adopters of the technologies. Military installations offer a controlled and safe environment for demonstrating emerging technologies and providing the critical feedback loop between the end-users and technology providers.

Military installations are often overwhelmed by requirements to meet Federal energy goals outlined in law, Executive Orders, and DOD directives with limited funding and existing commercial technologies that may or may not be competitive with conventional energy sources. However, identifying and establishing a select number of installations as "living laboratories" will allow R&D to be demonstrated and accelerate the commercialization of these technologies.

The idea of using military installations as demonstration test-beds is not new, but can be expanded, coordinated, and streamlined to ensure the greatest return. Using military installations as "living laboratories" offers a

safe and controlled environment to demonstrate and gain critical feedback on new technologies, and a streamlined and efficient process to insert emerging technologies. Often the initial steps (navigating the various installation processes and overlapping chains of command) are most difficult part of conducting a demonstration. There would be no need to repeat cumbersome initial steps at an established "living laboratory" installation, so the process could more systematically focus efforts on the technology demonstration itself. Installations would be fully aware of the difference between commercial and R&D technologies, and would be involved in evaluating the technologies on a case-by-case basis to establish "Technology Readiness Levels" (by using, for example, the sample "Technology Assessment Form" included in Appendix A to this report).

Establishing military installations as "living laboratories" would enable the DOD to bridge the gap between clean energy R&D and the resulting commercialized technologies by supporting technology demonstrations and by increasing the number of installations that may become early first adopters of these technologies. These two roles are inherently governmental. The government is far more capable than many commercial technology providers of making the initial investment in clean energy R&D, and as a result can play a critical role in accelerating clean energy technologies to the commercial market place.

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Preface

This study was conducted for U.S Army Tank Automotive Research Development Engineering Center (TARDEC), National Automotive Center under the Reliable, Secure, Efficient Energy Demonstration (RSEED), under Contract: DAAB07-03-D-B006, Delivery Order 0224.

The work was managed and executed by TARDEC. The CERL coordination was lead by Harold Sanborn in his role at TARDEC. The CERL Energy Branch (CF-E) provided project oversight and data from individual projects referenced in this report. René Parker is Program Manager, Select Engineering Services, under contract to TARDEC, through the Reliable, Secure, and Efficient Energy Demonstration (RSEED at Military Installations, Contract #DAAB07-03-D-B006, Delivery Order 0224. Erik Kallio is Transportation Energy Security Team leader, National Automotive Center, TARDEC. Franklin H. Holcomb is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. Jeffery P. Holland.

1 Introduction

Background

The impacts of current high levels of energy consumption (rising energy costs, dependence on foreign oil, and greenhouse gas emissions from fossil fuels) are national and global concerns. As conventional energy resources become more limited and difficult to access, energy prices will increase and world economics will be affected. The resulting shift in global economics between energy "haves" and "have nots" will likely lead to greater political instability as countries vie for positions of power and control over finite resources.

Declining energy security necessarily affects national security. The continental United States depends on an aging electrical grid and on imported oil. In theatre, the U.S. Department of Defense (DOD) has a growing demand for fuel (to support aircraft, ground vehicles and generators) that is costly to purchase and dangerous for U.S. soldiers to protect and deliver. These circumstances combine to significantly impact U.S. national security and the overall U.S. economy. President Obama's February 2009 Address to a Joint Session of Congress, contained a poignant statement that the country that harnesses the power of clean, renewable energy will lead the 21st century:

> We know the country that harnesses the power of clean, renewable energy will lead the 21st century ... but to truly transform our economy, protect our security, and save our planet from the ravages of climate change, we need to ultimately make clean, renewable energy the profitable kind of energy. —President Obama (2009)

This connection between energy, climate, and security was echoed by General Gordon R. Sullivan, USA (Ret.), former Chief of Staff, U.S. Army; former Chairman of the CNA Military Assessment Board. In a May 2009 CNA Report, *Powering America's Defense: Energy and the Risks to National Security* (Goodman 2009), General Sullivan stated:

> Energy, security, economics, climate change—these things are connected ... And the solutions will need to be connected. It will take the industrialized nations of the world to band together to demonstrate leadership and a willingness to change ...

> And here, I'd say the U.S. has the responsibility to lead. If we don't make changes, then others won't.

General Sullivan also responded to the hesitation by some to gather more concrete data on climate change before responding in the context of his military training:

> Military professionals are accustomed to making decisions during times of uncertainty. We were trained to make decisions in situations defined by ambiguous information and little concrete knowledge of the enemy intent even if we do not have complete information; you still need to take action. Waiting for 100 percent certainty during a crisis can be disastrous.

Underlying these statements is a call for an even greater commitment to clean energy Research and Development (R&D). There is a need for immediate "game changing" technologies that position clean energy as the environmentally and economically sound choice. R&D is the pathway to discovering these "game changing" technologies that will increase efficiency and reduce costs. As a result, the Federal government will need to play an even greater role in this area, by making larger investments in R&D, by providing demonstration sites, and/or by becoming early first adopters of promising new technologies.

Existing energy policy has set aggressive energy goals for Federal agencies. Legislation currently making its way through Congress indicates that energy will receive even greater attention in the years to come. Aggressive goals to reduce energy consumption will be coupled with goals that emphasize the reduction of greenhouse gas emissions. The linkage between energy and the environment promises to become even more pronounced. However, the transition from conventional energy to technologies that produce clean energy and that reduce greenhouse gas emissions will not be easy. The success or failure of new clean energy technologies depends largely on whether clean energy technologies can compete economically with conventional energy, or if the costs of conventional energy will be allowed to rise to a level that makes the cost of clean energy relatively competitive. A strong R&D focus is necessary to successfully effect cost-effective clean energy solutions.

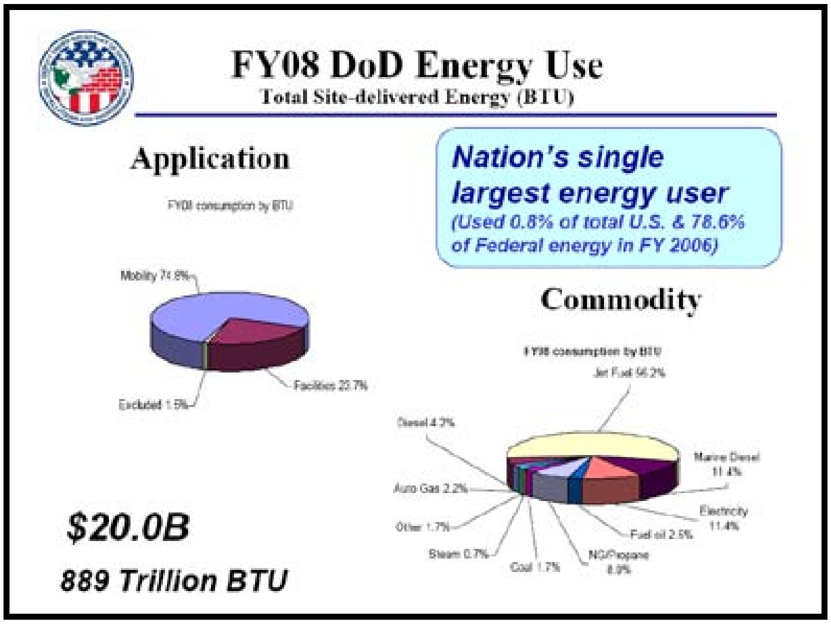

Figure 1. DOD energy use FY08.

The Role of DOD

The DOD, which is the nation's single largest energy user, maintains 536 installations, 545,714 facilities, and 29.8 million acres of land, and consumed 889 trillion BTU in fiscal year 2008 (FY08) at a cost of and $20 billion (Figure 1). The magnitude of these numbers highlights the unique role DOD can play in implementing and accelerating clean energy technologies.

To accomplish its mission, the DOD needs energy that is reliable, secure, clean, and affordable. To this end, DOD has begun to diversify its energy resources while conserving and managing its existing energy more effectively. In fact, the Defense Science Board has made a recommendation that would require all DOD installations to meet a "Net Zero Energy" standard by 2025 (i.e., each installation would produce as much or more energy than it consumes).

Although DOD is actively pursuing and implementing commercial-off-the-shelf, clean energy technologies, there is an overwhelming need to continue R&D in combination with systems integration. The DOD is in a unique position to assist by providing basic and applied research, and also demonstration sites for pre-commercial energy technologies. Installations provide a safe, secure location and knowledgeable workforce to conduct demonstrations. Private companies benefit from this arrangement by receiving first hand feedback from potential customers, real-world evaluation in a relevant environment, and the credibility of having demonstrated a technology with a government customer.

This work expands the definition of the role of DOD R&D as it relates to clean energy and how DOD can help bridge the gap between R&D and commercialization. This work was undertaken to address technology opportunities at fixed installations and to explore the role DOD R&D can play in commercialization and the importance of receiving real-world feedback on new technologies that meet both commercial and unique military needs. This work also addresses how demonstrations on fixed installations can assist in more rapid deployment of new technologies to theatre, and discusses how “living laboratories” can complement the concept of a “train as we fight” approach on fixed installations to ensure that soldiers become familiar with new energy technologies before encountering them in theatre.

Objectives

The objectives of this stage of work were to:

1. Provide a brief overview of the Technology Readiness Levels
2. Present a method to determine if a technology is “commercial” or “R&D”
3. Make recommendations on how to create “Living Laboratories” on installations to demonstrate clean energy R&D.

Approach

This concept report addresses the following issues:

1. A review of Federal energy policy (Chapter 2)
2. The role of R&D in meeting DOD needs, specifically with regard to energy issues (Chapter 3)
3. Measures of “Technology Readiness” (Chapter 4)
4. Commercialization of technologies (Chapter 5)
5. The role of installations as “living laboratories” (Chapter 6).

Chapter 8 includes several case studies of energy-related studies done at Army installations.

Scope

Although this report focuses on U.S. Army installations, it should be noted that the DOD has an extensive organization of tri-service (Army, Navy, and Air Force) R&D laboratories with diverse research focus areas. Leveraging the combined expertise and resources of these organizations along a common vision may increase the pace of successful integration across the services.

Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2 Federal Energy Policy

Overview

Federal energy policy has been evolving and expanding for years (Figure 2). Attempting to reconcile the goals and objectives of the entire body of Federal policy can be a large task. Achieving practical, near-term energy goals is most effectively completed by implementing "commercial-off-the-shelf" technologies that have a reasonable payback period (less than 10 years). However, as goals become more aggressive, it is important to continue the R&D of new energy technologies that will offer increased efficiency and lower costs.

Four principal Federal Energy Policies are currently in effect:

1. Energy Policy Act of 2005 (EPACT 2005)
2. Energy Independence and Security Act of 2007 (EISA 2007)
3. Executive Order 13423
4. Executive Order 13514.

Each policy sets goals for reduced dependence on fossil fuel, reduced energy consumption, reduced greenhouse gas emissions, increased energy efficiency, increased use of renewable energy, and increased use of alternative transportation fuels. Table 1 lists these policy goals.

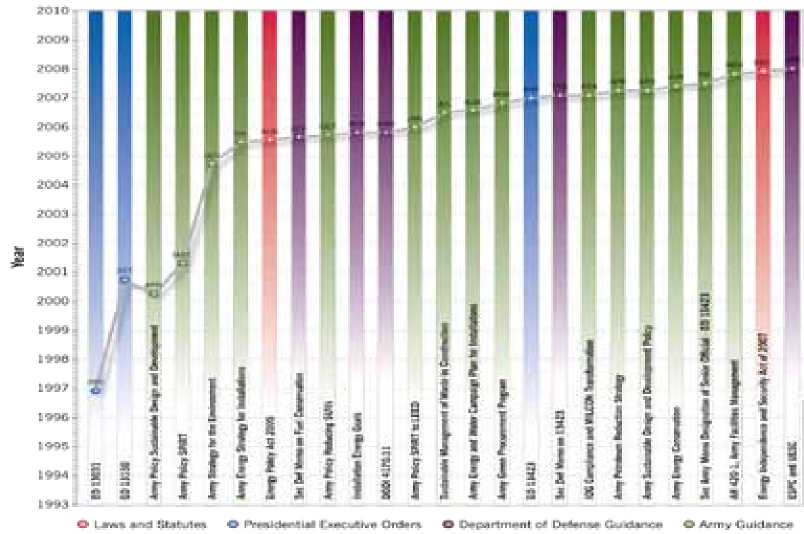

Figure 2. Key energy directives.

Table 1. Energy directives for fixed installations.

Directive Topic	Energy Performance Target	Source
Installations energy use	Reduce by 3% per year from FY08-FY15 ending in a 30% reduction in energy intensity by 2015 from 2003 baseline.	EO13423 EISA 2007
Electricity consumption from renewable sources	Must be 3% in FY09, 5% in FY 10-FY12, and 7.5% in FY12 and beyond	EPAct 2005
Electricity consumption from domestic renewable sources	A voluntary “sense of congress” goal to provide 25% by 2025	EISA 2007
Non-tactical vehicle (NTV) fuel consumption	Reduce 2% annually through 2015, 20% total by 2015 using a 2005 baseline	EO13423
Fossil fuel use in new/renovated buildings	Reduce 55% by 2010; 100% by 2030 relative to 2003 level	EISA 2007
Hot water in new/renovated buildings from solar power	At least 30% of hot water demand in new or substantially modified Federal buildings must be met using solar hot water heating by 2015, if life-cycle cost effective.	EISA 2007
Non-petroleum fueled vehicles use (ethanol, natural gas)	Increase by 10% annually until 100% of fleet is fueled by non-petroleum-based fuel	EO13423
Energy metering for improved energy management	Meter electricity by Oct 2012 and meter gas & steam by Oct 2016	EPAct 2005 EISA 2007

Federal energy policy has historically applied to the Department of Defense at the fixed installation level, with deployed operations exempted from the requirements. However, attention was placed on energy in the battlefield when, then Major General Rick Zilmer, commander of the deployed Marine forces in Al-Anbar Province Iraq, sent a communication from the field stating that “reducing the military’s dependence on fuel for power generation could reduce the number of road-bound convoys …

without this solution [renewable energy systems], personnel loss rates are likely to continue at their current rate" (Shaffer 2009).

Major General Zilmer suggested in strong terms the military R&D activities needed to accelerate readiness of alternative energy adoption to reduce petroleum consumption. As a result of this communication, the DOD recognized the importance of energy in theatre and began to investigate ways to implement near term energy reduction measures while looking towards the implementation of renewable energy resources to help support growing energy needs.

More Fight-Less Fuel

A Report of the Defense Science Board on Department of Defense Energy Strategy, *More Fight-Less Fuel* (DSB 2008) identified two primary energy challenges within DOD:

1. Unnecessarily high and growing battle-space fuel demand that:
   a. Compromises operational capability and mission success
   b. Requires an excessive support force structure at the expense of operational forces
   c. Creates more risk for support operations than necessary
   d. Increases life-cycle operations and support costs.
2. Almost complete dependence of military installations on a fragile and vulnerable commercial power grid and other critical national infrastructure, [which] places critical military and Homeland defense missions at an unacceptably high risk of extended disruption.

The articulation of these two energy challenges recognizes the importance of energy both at fixed installations and in theatre. The report goes on to suggest five recommendations to address these energy challenges:

1. Accelerate efforts to implement energy efficiency Key Performance Parameters (KPPs) and use the Fully Burdened Cost of Fuel (FBCF), to inform all acquisition trades and analyses about their energy consequences, as recommended by the 2001 Task Force.
2. Reduce the risk to critical missions at fixed installations from loss of commercial power and other critical national infrastructure.
3. Establish a Department-wide strategic plan that establishes measurable goals, achieves the business process changes recommended by the 2001 DSB report and establishes clear responsibility and accountability.

4. Invest in energy efficient and alternative energy technologies to a level commensurate with their operational and financial value.
5. Identify and exploit near-term opportunities to reduce energy use through policies and incentives that change operational procedures.

Army Energy Strategy and Campaign Plan

From an Army fixed installation perspective, primary guidance comes from the *Army Energy Strategy and Campaign Plan*, which lays out five major initiatives:

1. Eliminate energy waste in existing facilities
2. Increase energy efficiency in renovation and new construction
3. Reduce dependence on fossil fuels
4. Conserve water resources
5. Improve energy security.

Army Energy Security Implementation Strategy

The *Army Energy Security Implementation Strategy* (Army Senior Energy Council 2009) includes the following Vision, Mission, and Goals.

Vision

An effective and innovative Army energy posture that enhances and ensures mission success and quality of life for the Soldiers, Civilians, and their Families through Leadership, Partnership, and Ownership, and that also serves as a model for the nation.

Mission

Make energy a consideration for all Army activities to reduce demand, increase efficiency, seek alternative sources, and create a culture of energy accountability while sustaining or enhancing operational capabilities.

Goals

1. Reduced energy consumption
2. Increased energy efficiency across platforms and facilities
3. Increased use of renewable/alternative energy
4. Assured access to sufficient energy supplies
5. Reduced adverse impacts on the environment.

Achieving these aggressive goals has been challenging, as most Federal agencies must rely on existing Operations and Maintenance (O&M) budgets or third party financing. Meeting existing energy goals and striving to achieve future goals calls for a two pronged approach:

1. Implementation of commercial-off-the-shelf technologies with payback periods of less than 10 years to achieve near term goals
2. Continued and coordinated R&D to increase efficiency and reduce costs of clean energy technologies.

Energy policy will continue to evolve over the next 4 years. Congress is currently considering energy and greenhouse gas emission legislation. In addition, Executive Order 13514 (signed on 05 October 2009) extends Executive Order 13423 by expanding energy reduction and by making environmental greenhouse gases a priority. Most notably, the new Executive Order directs a 30 percent reduction in petroleum consumption by 2020, reducing potable water consumption intensity by 26 percent by the end of 2020 and directing that all Federal buildings be designed, beginning in 2020, to achieve net-zero energy by 2030 (Table 2).

Table 2. Energy goals/targets from the crosswalk of sustainability goals and targets in Executive Orders and statutes.

Goal / Target	EO 13423	EO 13514	Existing Statute
Building Energy	Reduce building energy intensity 3% annually through FY 2015, or 30% total reduction by FY 2015 (baseline FY 2003). [§2(a)]	Reduce energy intensity in buildings to achieve GHG reductions. [§2(a)(i)]	[EISA §431]: Reduce building energy intensity 3% annually through 2015, or 30% total reduction by 2015 (baseline 2003).
Renewable Energy Consumption	Ensure that 50% of statutorily required renewables comes from "new" (as of 1999) sources. [§2(b)]	Increase use of renewable energy. [§2(a)(ii)]	[EPAct 2005 §203]: Defines "renewable energy." [EPAct 2005 §203]: Increase renewables 3% in FY2007-2009; Increasing to 5% in FY 2010-2012. Increasing to 7.5% in FY 2013 and beyond. [EISA §523]: 30% of hot water demand in new Federal buildings and major renovations must be met with solar hot water if life-cycle cost effective.
Fleet Petroleum Use	Reduce by 2% vehicle petroleum annually through FY2015 (baseline FY2005). [§2(g)] Achieve 10% increase in non-petroleum fuel consumption annually (baseline FY2005). [§2(g)] Use plug-in hybrids when PIH are commercially available at a life-cycle cost reasonably comparable to non-PIH vehicles. [§2(g)]	Reduce fleet's consumption of petroleum products 2% annually through end of FY 2020 (baseline FY 2005). [§2(a)(iii)(C)] Use low-GHG-emitting vehicles. [§2(a)(iii)(A)] Optimize number of vehicles in fleet. [§2(a)(iii)(B)]	[EISA §142]: Reduce vehicle petroleum reduction 20% by FY 2015 (baseline FY2005). [EISA §142]: Achieve 10% increase in non-petroleum fuel use annually by 2015 (baseline 2005). [EISA §246]: Install at least one renewable fuel pump at each Federal fleet fueling center by 2010. [EISA §141]: Federal agencies are prohibited from acquiring any light-duty motor vehicle or medium-duty passenger vehicle that is not a "low greenhouse gas emitting vehicle." Alternatively, an agency may demonstrate that it has adopted cost-effective policies to reduce petroleum consumption to achieve a comparable reduction in GHGs. [EPAct 2005 §701]: Dual-fueled vehicles to be operated on alternative fuel unless waivered.
Renewable Energy Generation	Implement new renewable energy generation projects on agency property for agency use. [§2(b)]	Implement renewable energy generation projects on agency property. [§2(a)(ii)]	[EPAct 2005 §203]: Double count renewable energy produced on Federal or Indian lands and used on-site at Federal facilities.
Energy Efficiency in New Construction and Major Renovations		Achieve by 2030 zero-net-energy in buildings entering the planning process after 2020. [§2(g)(i)]	[EPAct 2005 §109]: Achieve energy performance 30% beyond ASHRAE 90.1-2004. [EISA §433]: New Federal buildings and Federal buildings undergoing major renovations shall reduce their fossil fuel-generated energy consumption (baseline 2003) by 55% (2010), 65% (2015), 80% (20202), 90% (2025), and 100% (2030).

Goal / Target	EO 13423	EO 13514	Existing Statute
High Performance Sustainable Buildings	Ensure all new agency construction and renovation complies with the *Guiding Principles*. [§2(f)] Ensure 15% of existing Federal building inventory incorporate the *Guiding Principles* by 2015. [§2(f)]	Ensure all new construction, major renovation, or repair and alteration complies with the *Guiding Principles*. [§2(g)(ii)] Ensure 15% of existing facilities and building leases (above 5,000 gross square feet) meet the *Guiding Principles* by FY 2015. [§2(g)(iii)] Make annual progress towards 100% conformance with the *Guiding Principles.* [§2(g)(iii)]	[EISA §433]: Requires sustainable design principles be applied to the siting, design, and construction of buildings subject to the standards. [EISA §434]: Ensure major replacements of installed equipment, renovation, or expansion of existing space employ the most energy-efficient designs, systems, equipment, and controls life-cycle cost effective. [EISA §435]: As of December 19, 2010, Federal agencies are prohibited from leasing buildings that have not earned the ENERGY STAR label (some exemptions apply). [EPAct 2005 §109]: Includes application of sustainable design principles for new buildings.
Advanced Metering and Measurement			[EPAct 2005 §103]: Federal buildings must be metered by October 1, 2012 with data provided at least daily and electricity consumption measured hourly. [EISA §432]: Identify "covered facilities" constituting at least 75% of the agency's facility energy use. Each covered facility must have an energy manager designated and meet additional requirements. Energy and water evaluations must be completed every 4 years for each facility. Facility energy managers are also responsible for commissioning equipment and establishing O&M plans for measuring, verifying, and reporting energy and water savings. [EISA §434(b)]: By October 16, 2016, each agency shall provide for equivalent metering of natural gas and steam.
Green Roofs		Minimize consumption of energy, water, and materials through cost-effective, innovative strategies, such as highly reflective and vegetated roofs. [§2(g)(iv)]	
Building Portfolio Management		Manage existing building systems to reduce consumption of energy, water, and materials. [§2(g)(v)] Identify alternatives to renovation that reduce existing assets' deferred maintenance costs. [§2(g)(v)] Identify opportunities to consolidate and dispose of existing assets, optimize real property portfolio performance, and reduce environmental impacts. [§2(g)(vi)]	

Source: DOE Office of Environmental Policy and Assistance sustainability crosswalk.

3 Research and Development

Why is R&D important?

R&D is critical to the discovery of innovative solutions to problems that face our nation.

While providing testimony to the U.S. House of Representatives' Committee on Energy Independence and Global Warming, Daniel Kammen, Director of the Renewable and Appropriate Energy Laboratory at the University of California at Berkley, was asked why R&D investment matters. He responded that:

> Innovation is the life-blood of economic growth and renewal, in fact, it has been known for decades that the bulk of new economic growth results from the re-invention and invention of new scientific and technological opportunities.

Mr. Kammen went on to state that "investment in research and development is roughly three percent of the gross domestic product and just one-tenth of the R&D budget goes to the energy sector." He further provided the example of solar photovoltaics, which experienced a 50 percent increase in efficiency immediately after an unprecedented $1 billion global investment in PV R&D from 1978-1985 (Bruno 2009).

Today, the total Federal R&D FY2009 budget is $151.1 billion (an increase of 4.7 percent above the FY2008 estimate). However, Federal research investments continue to shrink as a share of the U.S. economy (Koizumi 2009) (Figure 3). This is in contrast to Asian countries (China and South Korea) that are boosting their investments 10 percent or more annually.

The Administration has begun to focus additional attention on R&D and is seeking innovative solutions to address the nation's energy problems. This focus can be seen in the recent launch of the Advanced Research Projects Agency-Energy (ARPA-E) program that was initially established in 2007 by the American COMPETES Act (P.L. 110-69).

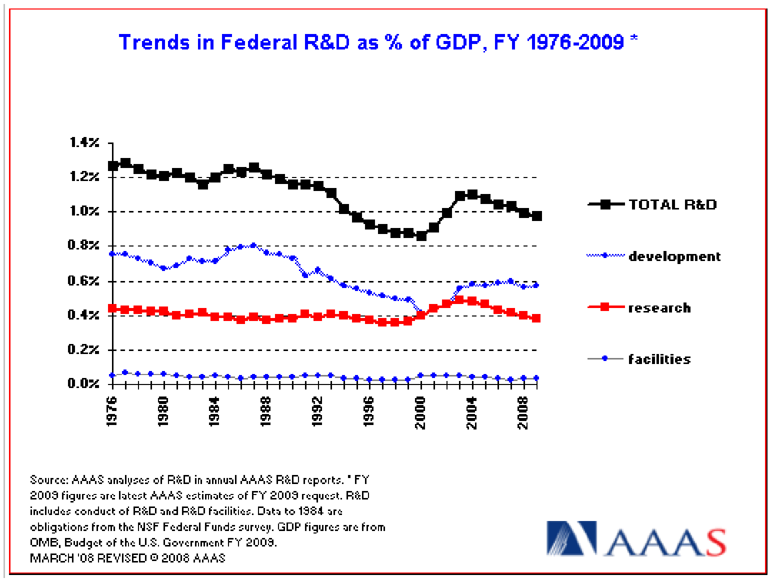

Figure 3. Trends in Federal R&D.

ARPA-E was authorized funds in 2007, but those funds were never appropriated. Congress later added $400 million from American Recovery and Reinvestment Act to another $15 million in FY2009 funds to launch the agency (Stine 2009). This agency was modeled after the Defense Advanced Research Projects Agency (DARPA). The goals of ARPA-E are to:

1. Enhance the economic and energy security of the United States through the development of energy technologies that result in reductions of imports of energy from foreign sources; reductions of energy related emissions including greenhouse gases, and improvement in the energy efficiency of all economic sectors
2. Ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

These goals are to be a achieved by identifying and promoting revolutionary advances in fundamental sciences, translating scientific discoveries into technological innovations, and accelerating transformational technological advances in areas that industry might not undertake due to technical and financial uncertainty (USDOE Undated). The initial solicitation for concept papers for the ARPA-E program were due June 2009 and the DOE expects to award $150 million of the $415 million FY2009 budget.

The ARPA-E program is modeled after the DARPA program. DARPA was created as the Advanced Research Projects Agency (ARPA) in February 1958. Its creation was directly attributed to the launching of Sputnik and to U.S. realization that the Soviet Union had developed the capacity to rapidly exploit military technology. Additionally, the political and defense communities recognized the need for a high-level DOD organization to formulate and execute R&D projects that would expand the frontiers of technology beyond the immediate and specific requirements of the Military Services and their laboratories.

In addition to the ARPA-E program, the administration issued guidance on 04 August 2009 to all heads of Executive Departments and Agencies, directing them to prepare their FY2011 budget submissions in such a way as to shift funds from lower-priority areas to science and technology that address four practical challenges (White House 2009):

1. Applying science and technology strategies to drive economic recovery, job creation, and economic growth
2. Promoting innovative energy technologies to reduce dependence on energy imports, and mitigate the impact of climate-change while creating green jobs and new businesses
3. Applying biomedical science and information technology to help Americans live longer, healthier lives while reducing health care costs
4. Assuring the existence and availability of technologies needed to protect U.S. troops, citizens, and national interests, including those needed to verify arms control and nonproliferation agreements essential to our security.

Federal R&D

The FY2009 Federal R&D budget saw an across the board increase for the first time in 4 years. The total Federal R&D budget for FY09 is $151.1 billion (4.7 percent increase over FY2008). Figure 4 shows the percentage increase over the FY2008 budget across Federal agencies. Department of Energy R&D saw a 21 percent increase in their budget. Although, this is a positive step forward, it still falls short of the investment that is needed to achieve “game-changing” energy innovation.

The U.S. percentage of investment based on GDP is less than 1 percent. By contrast, most Asian countries are investing in government R&D at a rate of 10 percent annually (Koizumi 200). Figure 3 (p 14) shows R&D investment trends as a percentage of GDP from 1976-2009. Currently, Defense R&D makes up 57 percent of the total Federal R&D portfolio in FY2009 appropriations, $86.2 billion (AAAS 2009). Figure 5 shows the Federal R&D investment trend from 1991-2009 by military service.

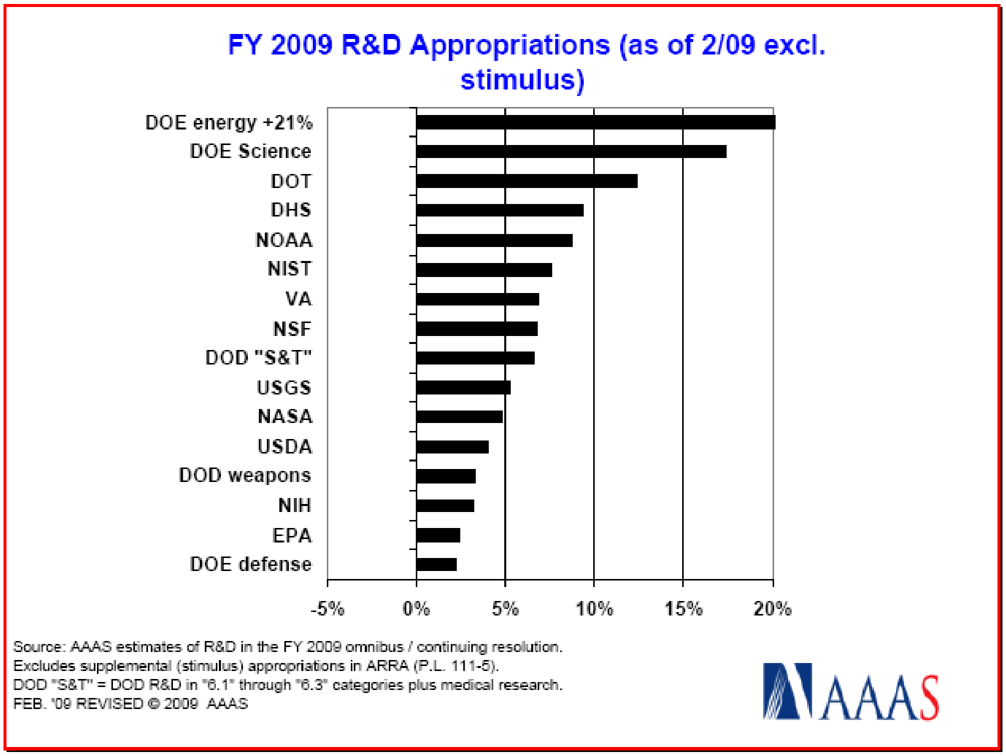

Figure 4. R&D appropriations (FY09).

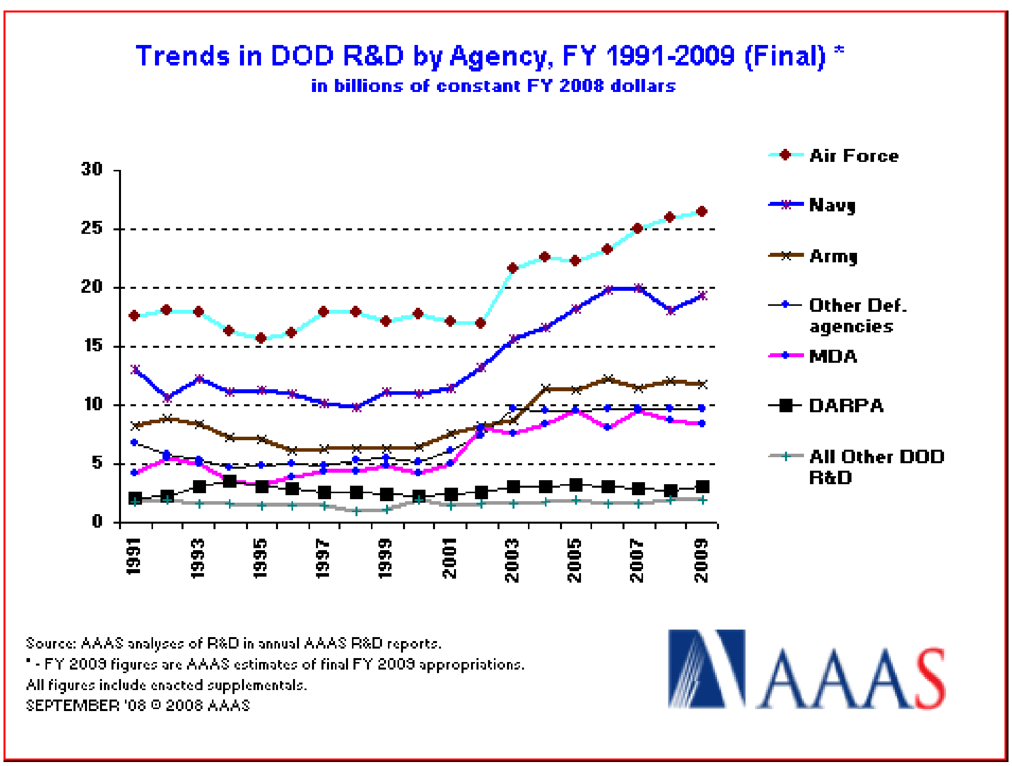

Figure 5. Trends in DOD R&D FY91-FY09.

DOD R&D

R&D in the DOD is led by the Director of Defense Research and Engineering (DDR&E) and reports to the Under Secretary of Defense for Acquisition, Technology, and Logistics (AT&L). The mission of DDR&E "is to ensure that the warfighters today and tomorrow have superior and affordable technology to support their missions, and to give them revolutionary war winning capabilities" (DDR&E 2009).

The DARPA organization (Figure 6) is of particular note. As discussed previously, DARPA was the model for the development of the ARPA-E program and is considered to be the genesis of many dual-use technologies that grew out of DARPA's ability to take high risks in hopes of high returns. DARPA is the central DOD R&D organization. DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security. DARPA funds researchers in industry, universities, government laboratories and elsewhere to conduct high-risk, high-reward R&D projects that will benefit U.S. national security. The research runs the gamut of conducting basic, fundamental scientific investigations in a laboratory setting to building full-scale prototypes of military systems (DARPA 2009). DARPA is typically the first organization that many people think of when discussing DOD R&D. However, DARPA is only a piece of the total DOD R&D community.

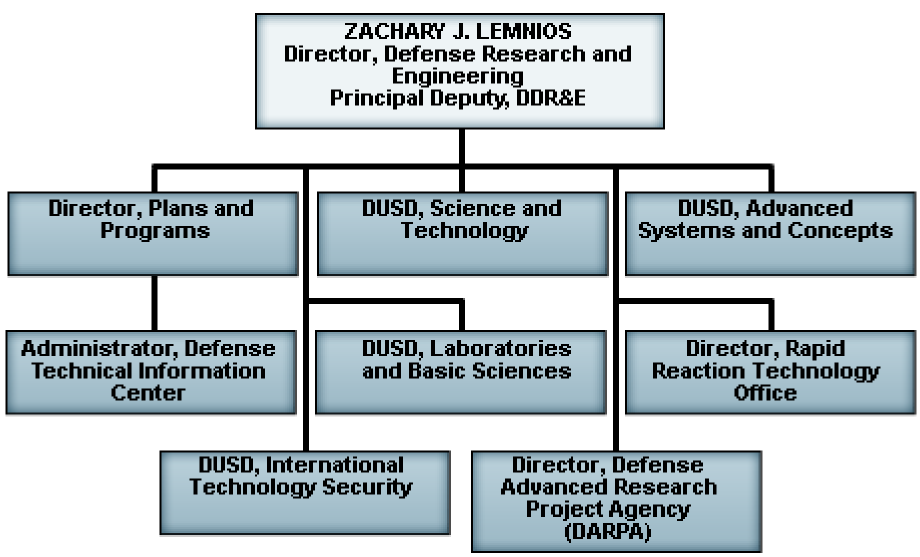

Figure 6. DDR&E organization chart.

First, it is useful to clarify some basic terminology used within the Department of Defense. The DOD uses the terms “R&D” and “Science and Technology (S&T)” interchangeably, according to a study by Rand Corporation entitled *International Cooperation in Research and Development* (Wagner 1997).

The DOD identifies three distinct budget categories (6.1 Basic Research; 6.2 Applied Research, and 6.3 Development), which in turn correlate with Office of Management and Budget (OMB) definitions. The DOD refers to these three categories as “S&T”:

1. *Basic Research*. Systematic study to gain knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind.
2. *Applied Research*. Systematic study directed toward greater knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
3. *Development*. Application of knowledge toward the production of useful materials, devices, and systems, or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements (Wagner 2009).

In addition, DOD delineates budget categories 6.4-6.7 as testing, evaluation, and design activities and refers to these categories as R&D (Wagner 2009). All seven categories are included within the total Federal R&D budget.

The DOD has a very large laboratory system, with each service having its own areas of expertise and research capabilities. In fact, there are 42 Army, 20 Navy, and four Air Force laboratories (Frank 1993). As a result, there has been an attempt over the years to coordinate research efforts between and among the services to avoid duplication of efforts. (Note that this report focuses on Army R&D organizations.) Examples of U.S. Army R&D organizations are:

1. *U.S. Army Engineer Research and Development Center (ERDC)*, which conducts R&D in support of the Soldier, military installations, and the Corps of Engineers civil works mission, as well as for other Federal agencies and state and municipal authorities, and with U.S. industry — through innovative work agreements (Figure 7).

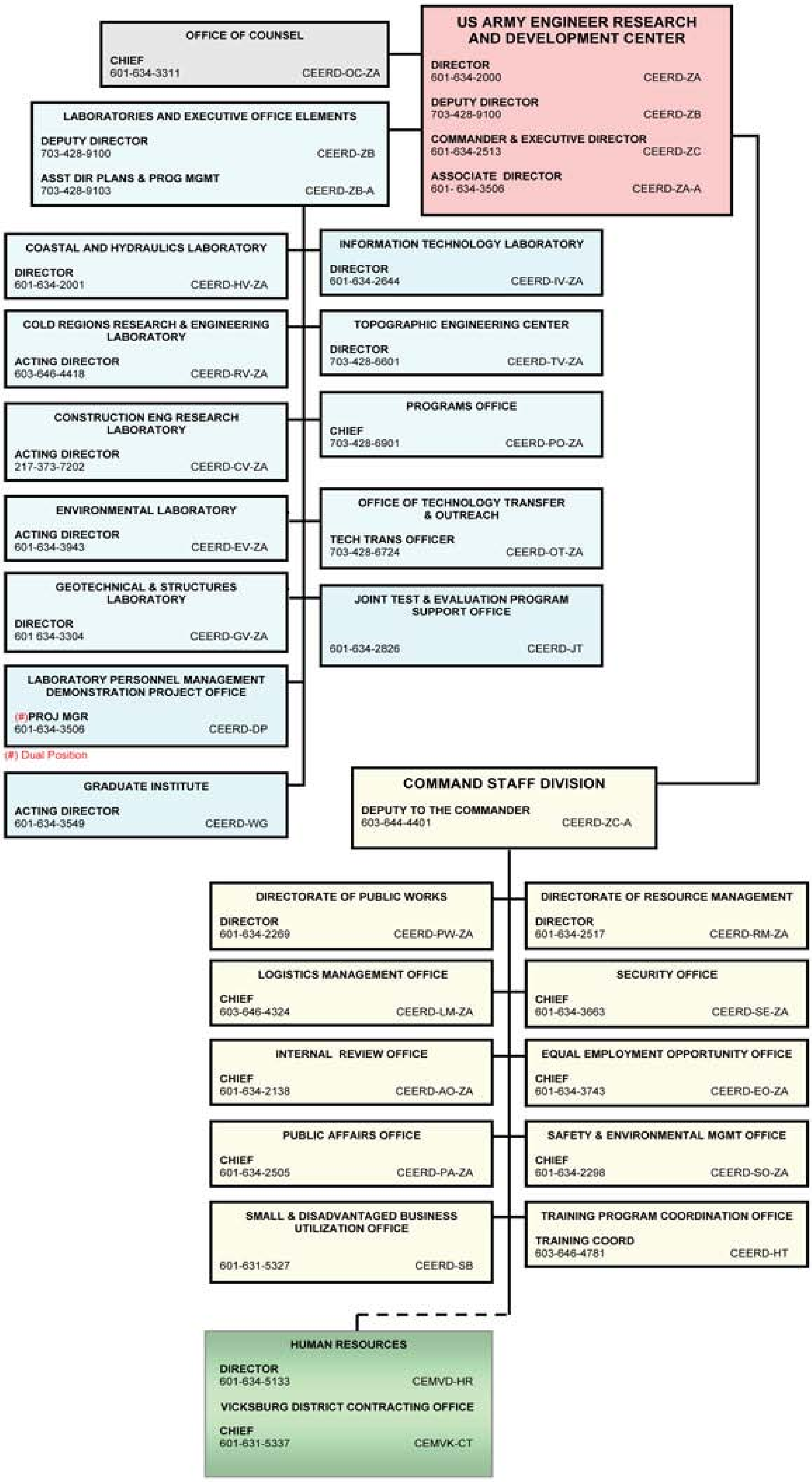

Figure 7. ERDC organization chart.

The ERDC synergistically addresses R&D through the capabilities of seven laboratories: Construction Engineering Research Laboratory in Champaign, IL; Cold Regions Research and Engineering Laboratory in Hanover, NH; Topographic Engineering Center in Alexandria, VA; and the Coastal and Hydraulics, Geotechnical and Structures, Environmental, and Information Technology Laboratories in Vicksburg, MS, in four major areas:

a. Military Engineering
b. Geospatial Research and Engineering
c. Environmental Quality/Installations; and
d. Civil Works/Water Resources.

2. *U.S. Army, Research, Development, and Engineering Command (RDECOM),* which was established to provide a full spectrum of basic research, development, and engineering, and analysis of Warfighter systems from concept to capability.

   RDECOM consists of 10 organizations, one of which is the Tank Automotive Research, Development, and Engineering Center (TARDEC). TARDEC's mission is to research, develop, engineer, leverage, and integrate advanced technology into ground systems and support equipment throughout the life cycle. A sub-component to TARDEC is the National Automotive Center, which serves as a conduit between government, industry, and academia to identify dual-use technologies to accelerate commercialization opportunities.

   TARDEC/NAC is primarily focused on R&D 6.3 and above. The close working relationships with industry help to identify dual-use technologies (technologies with both a military and commercial use) and enable demonstrations on fixed installations. TARDEC has expanded its engagement with ERDC-CERL to enable both infrastructure and transportation opportunities, to satisfy its charter, and to leverage the energy connection in meeting installation requirements.

3. *U.S. Army Rapid Equipping Force,* which equips operational commanders with commercial-off-the-shelf and government off-the-shelf solutions to increase effectiveness and reduce risk, insert future force technologies, ... validate concepts, and speed capabilities to the soldiers (U.S. Army 2009).

   The Rapid Equipping Force was established to rapidly respond to soldier requirements with a focus on emerging and COTS technologies that enhance survivability, improve force protection and increase lethality. An example of REF's efforts was a FY08 Joint Capability Technology Demonstration (JCTD) entitled Net Zero Plus. The purpose of JCTD's is to find, demonstrate, transition, and transfer the best operational capabilities to the warfighter.

The purpose of the Net Zero Plus JCTD was to leverage energy technologies to provide efficient structures, alternative/renewable power generation and smart distribution systems for Forward Operating Bases. A multitude of technologies are being demonstrated and evaluated for rapid deployment including spray foaming tents, monolithic domes with renewable energy sources, a tactical garbage-to-energy refinery and microgrid technologies.

These examples were chosen to show the breadth and depth of R&D within the Army focusing not only on the warfighter, but also on installations. All three organizations work closely with the end-user, whether an installation or a Soldier, to ensure that R&D aligns with needs and requirements and identifies a commercialization path for relevant technology.

Case studies will be presented later in this report on ERDC's Residential Hydrogen Fuel Cell Demonstration, RDECOM/TARDEC's PEM Hydrogen Fuel Cell Demonstration, and Mobile Encampment Waste to Electrical Power System Demonstration (MEWEPS). These case studies provide a look into the demonstration of pre-commercial clean energy technologies and the resulting outcomes.

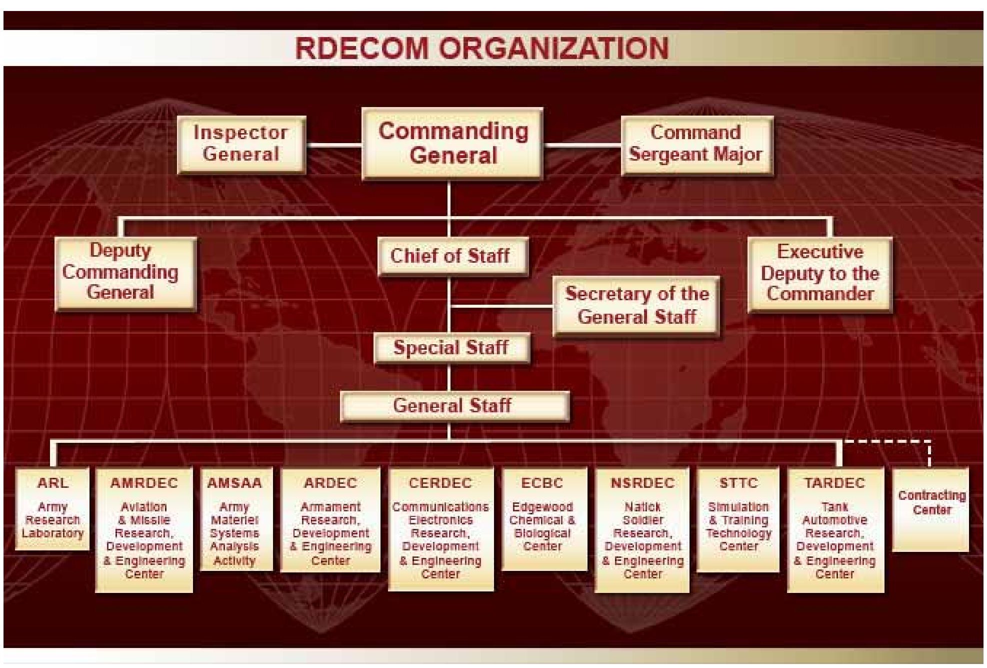

Figure 8. RDECOM organization chart.

4 Technology Readiness

A Technology Readiness Level (TRL) is a measure of the "maturity" of new technologies and an assessment of when they will be ready for incorporation into a developed system. The concept of the "TRL" originated with the National Aeronautics and Space Administration (NASA), but the DOD has established its own TRLs for hardware, software, and manufacturing. Table 1 lists TRLs for hardware, including definitions, descriptions, and supporting information. A TRL calculator may be downloaded from the Defense Acquisition University (Acquisition Community Connection 2009).

Table 3. DOD technology readiness levels.

TRL	Definition	Description	Supporting Information
1	Basic principals observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
4	Component and/or breadboard validation in a laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual systems. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and results from testing laboratory-scale breadboard(s). References to who did this work and when. Provide an estimate of how breadboard hardware and test results differ from the expected system goals.

TRL	Definition	Description	Supporting Information
5	Component and/or breadboard validation in a relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	Results from testing a laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match he expected system goals?
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in a simulated operational environment.	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving the next level?
7	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL6 by requiring demonstration of an actual system prototype in an operational environment (e.g., In an aircraft, in a vehicle, or in space). Examples include testing the prototype in a test bed aircraft.	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
9	Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.	OT&E reports.

The DOD requires all acquisition programs to have a formal Technology Readiness Assessment (TRA) at Milestone B and Milestone C. The TRA is a formal, systematic, metrics based process and accompanying report that assesses the maturity of critical hardware and software technologies. A formal TRA is required under DOD Instruction 5000.02 and the (AT&L) Memorandum on Transition of the Defense Space Acquisition Board (DASB) into the Defense Acquisition Board (DOD 2009). If a specific military application is identified for a technology, it follows the Defense Acquisition Process.

This process is very similar to the Commercialization process in that key milestones must be met to progress to the next level. Milestone B criteria is met when a technology has completed proof of concept and laboratory testing, and is moving into the prototype demonstration in a relevant environment. With each milestone achievement of the technology, there is the possibility of sustained development funding and the end goal of production, fielding, and sustainment within the DOD. Figure 9 shows a representation of the Defense Acquisition Management System. Combining the disciplined process of military acquisition with the commercialization process required by industry, on installations, is key to the idea of using the living laboratory concept.

However, TRLs can and should be used to assist in the determination of technology maturity even if the technology will not be entering the DOD acquisition process. Assessing the TRL of a given technology is helpful in establishing expectations of a technology and pursing the development of a technology with eyes wide open. Often emerging energy technologies receive negative feedback because they are “sold” as mature/commercial when they are actually still in the development phase. Using the TRL list provides an objective set of metrics against which a technology may be measured.

As mentioned previously, it is often difficult to determine what a commercial technology is and what is still pre-commercial/developmental. To assist installations make this determination, a Preliminary Technology Assessment Checklist has been developed that helps gather necessary information about the company and the technology, and that provides the appropriate questions to ask to determine the approximate TRL.

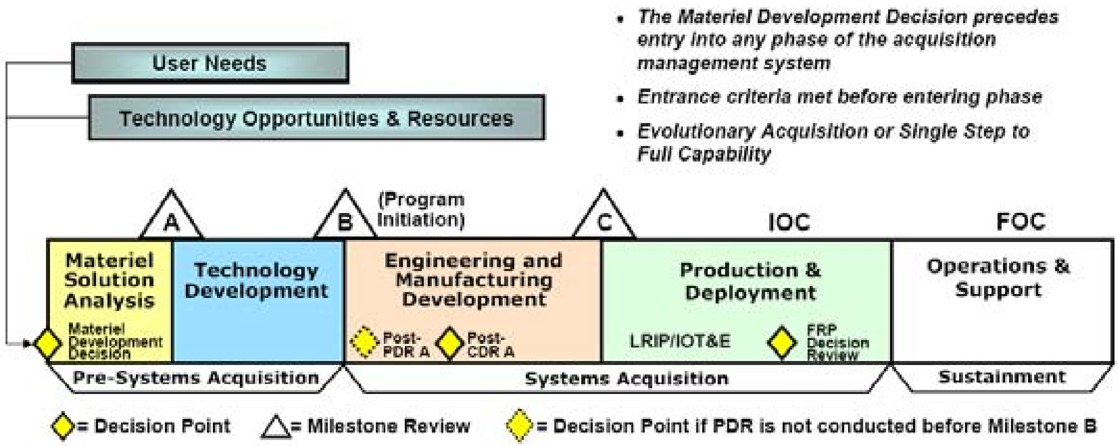

Figure 9. Defense Acquisition Management System.

Appendix A to this report includes the Preliminary Technology Readiness Checklist, which can be used any time a new technology is proposed. The gathered information may be shared with others within the organization and the R&D community. The key to advancing technology is to reduce the number of "false starts," which happen when technologies are sold as commercial when they are clearly still in development. Such false starts can negatively impact the overarching technology in a way that may take years to overcome. Neither the Warfighter nor the installation can afford false starts. It is absolutely necessary to accurately assess technology readiness.

5 Commercialization

The term "commercial," or "Commercial Off-the-Shelf (COTS)" refers to items (other than real property) that are of a type customarily used for nongovernmental purposes, and that have been sold, leased, or licensed to the general public. COTS are commercial items that require no unique government modifications or maintenance over the life cycle of the product to meet the needs of the procuring agency (U.S. Defense Acquisition University 2005). COTS technologies are typically available through the General Services Administration (GSA) and have warranties and service agreements. Pre-commercial technologies, on the other hand, do not offer warranties, are not mass produced, and often have a limited operational life.

Since the benefit of an invention cannot be realized until it is commercialized, there is a necessary emphasis on transferring technology from R&D to the commercial market. This can sometimes be more difficult than one would think, particularly within the area of clean energy.

The transition of clean energy technology into the market can often be more difficult because clean energy is seen as a "disruptive technology," which offer(s) a different value proposition. "Many of these new markets must be created and developed, while attempting to sell in existing markets where the entrenched competition is fierce and may have an unfair market advantage ..." (Alderfer, Eldridge, and Starrs 2000).

Figure 10 shows the typical commercialization path overlaid with cashflow versus sales and the types of funding required at each level. The "Valley of Death" occurs for most companies when attempting to take a technology from R&D to market. It is during this period that cashflow is limited and sales have not yet begun. This is the area in which DOD can play a significant role in the commercialization process.

Not only can public funding be provided to conduct demonstrations of the technology, but the government may, in some cases, be in a position to be become an early adopter by making a significant first buy of the technology. This type of DOD involvement can encourage private investment because the DOD (and government in general) is able to assume a higher amount of risk than is the private sector.

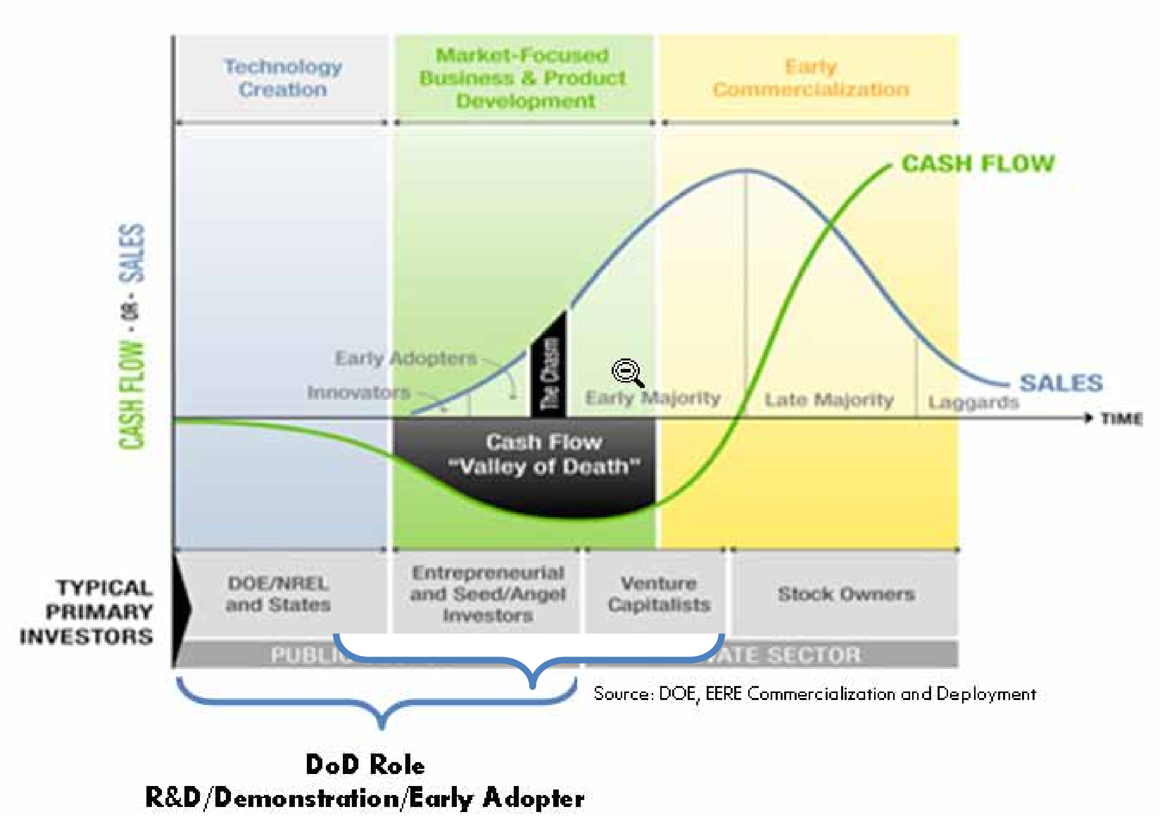

Figure 10. Commercialization process.

Figure 10 above also shows the categories of adopters from "Innovators" to "Laggards" and the curve at which innovation is adopted by each category. This is important to understand so that a solid business strategy can be established. The *Diffusion of Innovation* (Rogers 1995), categorizes "adopters" into five specific areas:

1. *Innovators*. Innovators are the first individuals to adopt an innovation. Innovators are willing to take risks, are youngest in age, have the highest social class, have great financial lucidity, are very social, and have closest contact to scientific sources, and interact with other innovators.
2. *Early Adopters*. Early Adopters are individuals who adopt an innovation after a short wait. These individuals have the highest degree of opinion leadership among the other adopter categories. Early adopters are typically younger in age, have a higher social status, have more financial lucidity, have advanced education, and are more socially forward than late adopters.
3. *Early Majority*. The Early Majority adopt an innovation after a varying degree of time. This time of adoption is significantly longer than the innovators and early adopters. The Early Majority tends to be slower in the

adoption process, has above average social status, has contact with early adopters, and shows some opinion leadership.

4. *Late Majority*. Individuals in the Late Majority will adopt an innovation after the average member of the society. These individuals approach an innovation with a high degree of skepticism and after the majority of society has adopted the innovation. Late Majority are typically skeptical about an innovation, have below average social status, have very little financial lucidity, are in contact with others in late majority and early majority, and show very little opinion leadership.
5. *Laggards*. Laggards are the last to adopt an innovation. Unlike some of the previous categories, individuals in this category show little to no opinion leadership. These individuals typically have an aversion to change-agents and tend to be advanced in age. Laggards typically tend to be focused on "traditions," have lowest social status, have lowest financial fluidity, are the oldest of all other adopters, are in contact with only family and close friends, and display very little to no opinion leadership.

The DOD is seen as a potential "Early-Adopter" because of government's ability to assume a greater level of risk and has the highest level of "opinion leadership" with the ability to communicate and persuade others to adopt a particular technology. However, in addition to the adopter categories is a set of innovation characteristics that determine the rate of diffusion. Rogers identifies these five characteristics as:

1. **Relative Advantage.** Degree to which an innovation is perceived as better than the idea it supersedes.
2. **Compatibility.** Degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters.
3. **Complexity.** Degree to which an innovation is perceived as difficult to understand and use.
4. **Trialability.** Degree to which an innovation may be experimented with on a limited basis.
5. **Observability.** Degree to which the results of an innovation are visible to others.

When conducting demonstrations of clean energy technologies on military installations, all five of these characteristics have an opportunity to present themselves. However, the primary purpose of a demonstration is to allow potential users to try a new technology within a controlled, safe environment and to observe first hand its operation and ability to fit within existing systems. Demonstrations are a vital component to commercialization and the overall rate of diffusion.

The potential impact on a market in which a technology is demonstrated and then is embraced by early-adopters is evident in a 2008 report published by Oak Ridge National Laboratory entitled *Bootstrapping a Sustainable North American PEM Fuel Cell Industry: Could a Federal Acquisition Program Make a Difference?* PEM fuel cells for back-up electric power are viewed as a near term market with the second near term market for fuel cells being material handling equipment. However, the rate at which the PEM fuel cell industry can achieve significant market penetration will impact the overall future of their industry. Therefore, the premise of the ORNL report was that the Federal government should take immediate action to make large scale purchases (up to 2000 units per year) of PEM fuel cells; thereby helping to increase the production volumes and lower costs (Greene and Duleep 2008).

Greene and Duleep present findings that estimate that the Federal back-up power market is nearly 20,000 units, approximately 75 percent of which could be replaced with fuel cells. Table 4 lists back-up power needs by Federal government market/application by agency and size (Mahadevan et al. 2007).

Table 4. Federal Backup power fuel cell applications by agency and size.

Market and Application	Market Size, units	Size of PEMFC (kW)	Total Annual Purchases	Total Annual Purchases of PEMFC	Cost Per PEMFC ($)	Installation Cost ($)	Cost (million $)
FAA - Radio Towers	15,000	1	1,750	1,313	6,740	4,000	14.1
DHS - Radio Repeater Towers and Border Entry Points	200	5	200	150	15,940	18,000	5.1
NOAA – Weather Radio, Automated Surface Observing Systems	1,824	5	122	91	15,940	18,000	3.1
NOAA - Upper-air Observations Program	800	1	53	40	6,740	4,000	0.4
USDA - Fire Incident Camps, Radio Repeater Sites	1,000	5	66	50	15,940	18,000	1.6
BoR – Communication Sites	100	5	7	5	15,940	18,000	0.2
DOD – Radio Transmitter Sites	1,000	1	67	50	6,740	4,000	0.5
Total	19,924		2,265	1,699			$27.1

At the time of this writing, the Department of Energy, Market Transformation Office and the Department of Defense are working together to identify military installations for a large purchase of back-up power fuel cells. This is the next logical step considering the considerable support the DOD has provided to the PEM Fuel Cell market conducting large scale demonstrations and now working towards a large scale purchase and installation of the commercial fuel cell product. This type of program has the potential to significantly impact the commercial market and accelerate the overall rate of adoption of PEM fuel cells.

Historically, technologies were developed for the military and then "commercial" applications were identified and spun off. That is not always the case anymore. The DOD is more commonly looking towards commercial products that can meet their needs without altering the product to meet military standards. This is an important point since DOD can now better align its needs with those of the commercial market and work in concert with private industry to develop technologies that will address a commercial market need and also fit a DOD application.

In addition, a new technology that may be created by a DOD laboratory or demonstrated on an installation may not address a specific "Defense" requirement, but may address a more broad commercial need. Collaboration with the DOD can be helpful when private companies are searching for additional investment dollars. The private investment community looks at a business' potential market base; and potential significant first-buys by the DOD can assist in securing private funding in the future. However, a company must be careful to diversify their funding and find several possible customers because too heavy a reliance on public funding may send a message to the private investment community that a company is not serious about commercialization and is stuck in the R&D world.

Not all companies created equal

The discussion of technology "commercialization" is often (but not always) associated with a start-up company. Start-up companies are different from established companies, which have an R&D budget, cash-flow, and established business practices that may make the commercialization of a technology slightly easier. Consequently, start-up companies sometimes face the additional challenges of general business development along with the commercialization of a particular technology.

The distinction is an important one to help the installation evaluate and establish realistic expectations for the technology. Start-up companies are more likely to fail in their commercialization efforts because they are attempting to cross over from the R&D phase to product commercialization while establishing its business practices and financing at the same time.

Many technically sound new technologies come from the laboratories and require the application of an additional level of business expertise to take them from the laboratory to market. Suppose, for example, a scientist who had never established nor run a business, were to discovers a new energy storage medium. The energy storage medium could well remain “undiscovered” because the technical subject matter expert was unable to navigate the business world.

With this is mind, it is important to understand the business that you are working with. Technology start-up companies should be encouraged to grow and prosper, with the applied systems integration offered by focusing on military applications. The number of tools available to military R&D organizations, to foster this development, are readily available and are illuminated later in this report.

Government is typically encouraged not to pick “winners and losers,” but on the other hand, government should understand business development, how the private sector conducts business, and how companies can best work collaboratively with government to achieve mutual goals.

The report *Transitioning to Private-Sector Financing: Characteristics of Success* (Murphy, Brokaw, and Boyle 2002) discusses how the private and public sector could best work together by understanding and leveraging appropriate resources. The report raised the concern that a private company that relies too heavily on public sector financing can in fact hurt their chances to receive private sector financing because the private investor may assume the company is more interested in “playing in the R&D sandbox” than in taking a market-focused approach to business development and commercialization. It is also important for a particular company to assess where it is, and where it needs to be for private investors to take an interest (Table 5). Table 6 lists the gaps that exist between a start-up company and investor “wants” when looking to invest.

Table 5. Qualifying requirements for the next round of financing.

	Financing Round	Who Typically Plays	Typical Qualifying Requirements for Next Round	Key Processes
Technology Creation	Bootstrapping Concept Generation	Entrepreneur	• Exciting technology concept, linked to a market need • Applications identified	• Research • Development • **Marketing**
Technology Creation	**Pre-Seed:** Technology Development	Personal / Public Support (e.g. DOE/ATP /SBIR/States)	• Key patents applied for/secured • Technical feasibility and initial commercial feasibility with prototype demonstrated • A plan for taking the business forward is available • Substantial market need quantified and competition identified	• Development • Engineering • **Marketing**
Market Focused Business Maturation	**Seed:** Prove a concept qualifies for start-up capital	Individual Angels Angel Groups Early-stage Venture Capitalists	• Business/commercialization plan available; • Specific markets, including competition, well characterized; and initial customers identified • Attractive market-ready products /or processes available • Management team identified	• Development • Engineering • Manufacturing • **Marketing**
Market Focused Business Maturation	**Start-up:** Complete product development and initial marketing	Select Individual Angels Angel Groups Early-stage Venture Capitalists	• Launch of commercial product and/or process • Strong management team in place • Rapidly expanding customer base	• Manufacturing • **Marketing**
Market Focused Business Maturation	**First:** Initiate full-scale manufacturing and sales	Venture Capitalists	• Large customer base, and still growing by new constituents • New products and new processes	• Research • Development • Engineering • Manufacturing • **Marketing**

Table 6. Enterprise development gaps as seen in many entrepreneurial clean energy companies.

	Start-up Clean Energy Companies Frequently Have	Investors Want
People	Strong technical expertise; a desire to retain ownership and control	Well-rounded and experienced management team; including start-up experience.
Product	Protected intellectual property position; technical benefits well defined; often still focused on technology and not on developing a marketable product	Protected intellectual property position; a clearly defined product or set of products; market drive and clear customer benefits well articulated
Strategy	Narrow technology focus with limited profitability horizon	Strong market focus with sustained high profitability and technology platforms, which allow for product and market diversification
Markets	Technology push; often oriented to attracting more sponsored R&D; competitive position not well defined	Market creation and technology pull; many identified customers (min. $100M/yr. Potential market opportunity) and poised for rapid growth; competition well understood
Financing	Inadequate justification and definition on amount of investment required or expected, return on investment (ROI) and exit strategy	Clearly defined plan for use of funds to grow business providing high ROI (40%) and a clear exit strategy (~5 yrs) described
Business Plan	Incomplete or nonexistent	A comprehensive and integrated picture of all of the above – to bring the technology to market

How private industry works with the DOD

There are several ways in which private companies can work with the DOD to develop and demonstrate their technologies. The most three most common mechanisms are the Cooperative Research and Development

Agreement (CRADA), Small Business Innovation Research, Small Business Technology Transfer (STTR):

1. A *CRADA* is an agreement established between Federal laboratories and commercial, academic, or non-profit partners to facilitate technology transfer between the parties for mutual benefit. Under a CRADA, the partner may contribute resources such as personnel, services, property, and funding to the effort. The government can contribute all the above, except funding.
2. The DOD *SBIR* program, funded at approximately $1.14 billion in FY 2008, is made up of 12 participating components: Army, Navy, Air Force, Missile Defense Agency (MDA), Defense Advanced Research Projects Agency (DARPA), Chemical Biological Defense (CBD), Special Operations Command (SOCOM), Defense Threat Reduction Agency (DTRA), National Geospatial-Intelligence Agency (NGA), Defense Logistics Agency (DLA), Defense Microelectronics Activity (DMEA), and the Office of Secretary of Defense (OSD). The SBIR program funds early-stage R&D at small technology companies and is designed to:
   a. stimulate technological innovation
   b. increase private sector commercialization of Federal R&D
   c. increase small business participation in Federally funded R&D
   d. foster participation by minority and disadvantaged firms in technological innovation.
3. The DOD *STTR* program, funded at approximately $132 million in FY 2008, is made up of six participating components: Army, Navy, Air Force, Missile Defense Agency (MDA), Defense Advanced Research Projects Agency (DARPA), and the Office of Secretary of Defense (OSD). In 1992, Congress established the STTR pilot program. STTR is similar in structure to SBIR, but funds cooperative R&D projects involving a small business and a research institution (i.e., university, Federally-funded R&D center, or nonprofit research institution). The purpose of STTR is to create, for the first time, an effective vehicle for moving ideas from our nation's research institutions to the market, where they can benefit both private sector and military customers.

In addition to these three programs, some private companies may receive “Congressional Adds (Earmarks),” grants or other funds made available through a competitive Request for Proposal process that provide funding to conduct R&D or demonstrations on DOD installations.

6 DOD Installations as "Living Laboratories"

The premise of this work is that DOD offers a unique opportunity to bridge the gap between R&D and commercialization by offering both R&D (basic, applied, development), and also demonstration of new technologies on installations, thereby creating the potential for installations to become early first adopters of the technology.

DOD installations are secure "cities," which must address issues related to growth, utilities, solid waste management, facilities, transportation, environment, security, etc. As a result, they offer a unique opportunity to serve as a "living laboratory" for emerging energy technologies because they are secure and controlled environments, in which soldiers/civilians are available to assist in demonstrations and provide critical feedback on technology. This type of controlled demonstration is important for the acceleration of clean energy commercialization because the technology provider can obtain real-world feedback on a technology's operation, maintenance, and applicability.

However, it is important for installations to realize that the role they fill as a "living laboratories" requires full participation and feedback, and implies an understanding that a technology being demonstrated may not always operate as intended; this is a part of the process. Installations must also understand that, depending on the TRL, some technologies may be able to remain in place after the demonstration, and others may be removed from the installation for further development based on what is learned during the demonstration.

First steps to a demonstration

Early buy-in by partners at the installation is absolutely necessary for a successful demonstration. When a technology provider or even an Army Laboratory approaches an installation with a request to use the location as a host site for a technology demonstration, it is important for the requestor to clearly understand and state the mission of the installation, and to state how the proposed demonstration will or will not impact that mission. An Army installation is much like a city; it has a formal approval process/structure that must be followed. The requestor must fully brief the Base Commander, who must grant approval of the demonstration. The requestor must also brief and request approval from these other organizations:

1. Department of Public Works
2. Energy Manager/Office
3. Environmental
4. Fleet Management
5. Security
6. Real Property
7. Contracting.

The requestor should also:

1. Conduct an assessment be to determine the best location for the demonstration and to establish any known baseline by which to compare the new technology
2. Initiate Environmental Impact Assessments (EIA) and Environmental Impact Statements (EIS) and any necessary permitting as soon as possible
3. Verify who can work on base (U.S. Citizens; non-citizens must be escorted at all times)
4. Establish the installation's requirements regarding type of contractor badges, vehicle passes, and normal working hours of the soldiers/civilians that will work with the demonstration.
5. Determine the type of support the installation can and will provide, such as heavy equipment, maintenance bays, tools, etc.

10 tips for conducting a successful demonstration

The following "tips" for conducting a successful demonstration can help technology providers prevent common problems:

1. Establish early buy-in from the installation-including leadership and soldiers/civilians assisting with the project
2. Ensure demonstration does not negatively impact the installation's mission or negatively impact the soldiers/civilians carrying out their normal duties
3. Establish the Team and put in place a communication plan to keep all parties informed throughout the process
4. Identify all necessary permitting and develop a schedule
5. Establish Standard Operating Procedures and Emergency Response Procedures
6. Coordinate with technology vendor for data collection and feedback on the operation of the technology

7. Provide appropriate training to installation personnel on the technology
8. Coordinate with the technology provider and installation for appropriate public information releases (press releases, tours, reports, etc.)
9. Provide regular status briefings and a final wrap-up meeting
10. Provide a final wrap-up briefing on the project and publish/share learning with other installations.

What the installation needs to know

Technology providers should be prepared to answer the following questions to quickly address installations' needs and concerns:

1. What are the benefits of the technology to the installation?
2. Has this technology been demonstrated before and where?
3. What are the objectives of the demonstration?
4. What resources will be provided to the installation to assist with the implementation of the demonstration?
5. What resources will the installation be asked to provide? Personnel, utilities, property, etc.?
6. What agreements need to be in place? CRADA, Memorandum of Agreement, Lease, etc.?
7. How long will the demonstration period last?
8. What hardware will be brought onto the installation?
9. What are the environmental impacts of the technology?
10. What is the return on investment for the technology, today and in the future?
11. What is the plan for disposition on completion of the demonstration? Is there a useful life to the technology and/or funding available to continue the demonstration beyond the initial demonstration?
12. What opportunities are there for future technology insertions?

What the technology provider needs to know

Before initiating a technology demonstration on an installation, technology providers should research (or ask the installation POC) the following questions:

1. What is the chain of command on the installation?
2. Will they work directly with the installation or a tenant on the installation?
3. Who are the decision makers and what agreements need to be in place?
4. What is government owned/operated and what is privately owned/operated?
5. What is the established energy (electrical, thermal, and gallons) baseline?

6. What is the cost of energy?
7. What are local community preferences and biases toward specific energy technologies?

Establishing DOD living laboratories

A novel approach to link R&D with potential customers and further accelerate the commercialization of technologies would be to establish a series of DOD Living Laboratories that would be identified in varying regions of the country (based on climates and energy resource availability, e.g., solar gain, biomass, geothermal, etc.) and varying missions (e.g., projection, training, etc.). These installations would agree to host demonstrations of emerging clean energy technologies and provide detailed feedback to the technology provider. This “one-stop-shop” approach to installation demonstrations would be facilitated by establishing:

- draft Memorandum of Understanding
- one-page checklist for permitting (streamlined permitting process)
- demonstration location with basic utilities available
- list of relevant points of contacts (energy manager, fleet manager, Department of Public Works, Environmental, etc.)
- clear understanding of installation chain of command and decision-making process.

Fixed installations offer a unique opportunity to demonstrate a technology that may one day become commercial and be implemented at the installation. However, fixed installations, particularly installations with a training mission and with mock forward operating bases may offer an opportunity to demonstrate emerging technologies that may be applicable to deployable applications.

A technology should never be deployed before undergoing a comprehensive evaluation and acquisition process. Installations such as the National Training Center at Fort Irwin, CA offer the ability to test various technologies that may one day be used in theatre. While the demonstrations are ongoing, the soldiers in training may become familiarized with the technology and may sometimes be trained on its use. This approach is consistent with the “train as we fight” concept. The soldiers should not be surprised by the technology in the field. Rather they should be knowledgeable of commercial and even emerging technologies that may be presented to them in theatre. For example, Case Study #3 (in Chapter 3, p 42) discusses a demonstration conducted at the Michigan National Guard Forward Operating Base in Camp Grayling, MI. The demonstration offered unique insight into the way the technology would operate if placed in its intended deployable application. This demonstration identified several areas for improvement before the technology continued on to military hardening and eventual deployment into theatre.

7 Case Studies

Case Study #1: DOD PEM fuel cell demonstration

Background

Between FY01 and FY04, ERDC-CERL conducted a DOD Residential Proton Exchange Membrane (PEM) fuel cell demonstration at DOD installations and DOD-related facilities (Figure 11). The objectives of the demonstration were to:

1. Assess the role of PEM fuel cells in support of DOD's training, readiness, mobilization, and sustainability missions
2. Assess fuel cells' role in supporting sustainable military installations
3. Increase DOD's ability to more efficiently construct, operate, and maintain its installations
4. Provide operational testing and validation of the fuel cell product to assess installation, grid interconnection, operation of systems in all seasonal conditions, and integration of units into an existing military base environment
5. Provide a technology demonstration site for a military base market
6. Stimulate growth in the distributed generation/fuel cell industry.

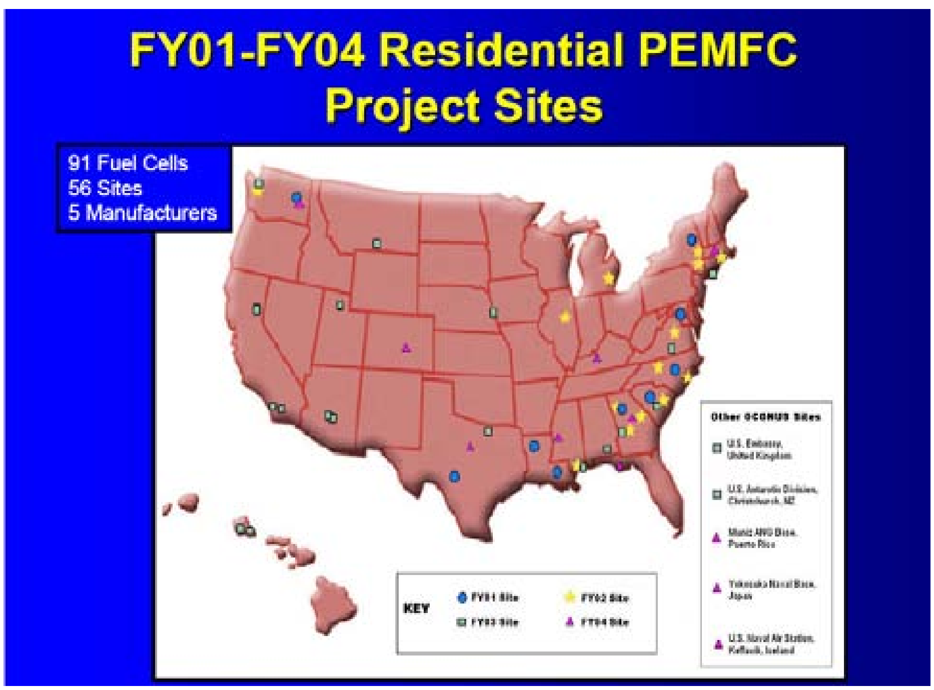

Figure 11. PEM fuel demonstration sites.

Keys to success

This project's success was greatly enhanced by:

- communication and coordination with demonstration site personnel
- the feedback loop between the demonstration site and technology provider

Lessons learned

The following valuable information was elicited during the demonstration:

- There is a vital need for a strong, reliable communication system with the fuel cell power plant to minimize downtime and avoid the cost of a technician on-site.
- PEM fuel cells are able to achieve a minimum 90 percent availability requirement.
- Back-up power is a viable DOD application for PEM fuel cells (specifically direct hydrogen fuel cells and cogeneration fuel cells systems that have a greater overall efficiency).

Accomplishments

The DOD PEM fuel cell demonstration program successfully:

- demonstrated 91 fuel cells at 56 sites
- provided valuable feedback to technology providers
- contributed to the technological advancement of PEM Fuel Cells.

Benefits

Largely due to the early demonstrations performed by ERDC/CERL, PEM fuel cells are now available for purchase through the General Services Administration. Although PEM fuel cells have passed the R&D phase, they must now achieve market penetration.

Case Study #2 NM National Guard Fuel Cell Demonstration

Background

The U.S. Army, TARDEC received a $1.1 million FY07 Defense appropriation for the demonstration of hydrogen fuel cells at the New Mexico National Guard (Figure 12). TARDEC partnered with the New Mexico National Guard to install and demonstrate 20 (5 kW) hydrogen fuel cells for emergency back-up power.

Figure 12. New Mexico National Guard Headquarters, Santa Fe, NM.

The demonstration ran from March 2008 to August 2009. After the demonstration, the fuel cells were left in place with a service agreement through December 2010. After December 2010, the New Mexico National Guard will be responsible for the continued support and maintenance of the fuel cells. Fuel cells were installed at five locations:

1. U.S. Property and Fiscal Office Building
2. Private Branch Exchange
3. Headquarters Building
4. Army Aviation Support Facility
5. Rio Rancho Armory.

Keys to success

This project's success was greatly enhanced by:

- buy-in from leadership
- coordination and collaboration with New Mexico National Guard personnel
- training of National Guard personnel on operation and general maintenance of the fuel cells
- local service providers (perform service calls and hydrogen refueling).

Lessons learned

The following valuable information was elicited during the demonstration:

- Maintain communication among partners (critical).
- Establish a project schedule and share with partners throughout the project.
- Plan for disposition and/or sustainment of equipment after the demonstration.
- Early involvement with the state fire marshal for siting of the fuel cells.

Accomplishments

The NM National Guard Fuel Cell Demonstration successfully:

- increased reliability (six service calls per year reduced to 1.3 calls per year)
- supported electrical load at the Santa Fe Army Aviation Support Facility during a 15-hr grid outage
- performed self-test diagnostics every 28 days for the duration of the demonstration
- completed extended testing.

Benefits

The New Mexico National Guard now has clean, reliable, and secure emergency back-up power. New Mexico National Guard personnel have received fuel cell training on the operation and maintenance of the fuel cells. Unexpected benefits included an opportunity for the New Mexico National Guard to identify critical energy needs and map electrical lines within the facilities.

Case Study #3 MEWEPS Demonstration

Background

The U.S. Army TARDEC contracted with ARINC, Next Energy Center and Community Power Corporation to develop and demonstrate a Mobile Encampment Waste to Electrical Power System (MEWEPS, see Figure 13) that would accept up to 2500 lb of military encampment waste per day to produce gas that would run a 60kW Tactical Quiet Generator (TQG). The system was to be contained in two ISO containers and capable of being transported and torn down/setup within 24 hrs and most importantly demonstrate a reduction in JP-8 and/or diesel consumption.

Figure 13. MEWEPS- Camp Grayling, MI, South FOB.

MEWEPS was designed, developed, and demonstrated both in a laboratory setting and then in the field. Each year the Michigan National Guard conducts annual trainings at the Camp Grayling Forward Operating Base (FOB). This FOB is set up to represent a deployed FOB and as a result was the perfect location for MEWEPS to be demonstrated. MEWEPS was demonstrated during the Michigan National Guard Annual Training at the FOB. Waste was collected and separated into paper, fiberboard, plastic, and some food. The system consisted of a Feedstock Processing Module (FPM) and a Gas Production Module (GPM). The waste was placed into an opening that dropped into a compactor to be sent through a shredder. Once the waste was shredded, it was delivered to a mixer that combined the material and added the necessary amount of moisture required to process the material into pellets. The pellets were then vacuum fed to the GPM that dropped the pellets into a downdraft gasifier that created producer gas, which was then used in a 60kW Tactical Quiet Generator. The power generated from the TQG was used in a 3HP water pump for troop showers and the remaining power went to a load bank. The MEWEPS is currently being transferred to Natick Soldier Center for further development and possible military acquisition.

Keys to success

This project's success was greatly enhanced by:

- Buy in from leadership
- Support of Michigan National Guard personnel

Lessons learned

The following valuable information was elicited during the demonstration:

- Match production with load to ensure proper electricity utilization.

Accomplishments

The MEWEPS demonstration successfully:

- achieved its goal of tear-down/set-up within 24 hrs
- achieved operation of the MEWEPS for 544 hrs (NextEnergy Center and Camp Grayling)
- achieved emission levels well under the Michigan Environmental Quality (MEDQ) Permit To Install (PTI) limits.

Benefits

The MEWEPS demonstration showed that the technology could:

- Minimize solid waste disposal
- Displace petroleum.

8 Conclusion and Recommendation

Without military R&D efforts, innovation to meet challenging energy and environmental goals is unlikely to pay off in time to satisfy those goals; and without commercialization, innovation will be more costly and less effective in the private sector. The vital link between military R&D and commercialization should be reinforced, and efforts taken to strengthen communication and coordination between the R&D community and the commercial market. DOD is uniquely positioned to bridge the gap between R&D and commercialization by implementing the concept of DOD installations as “living laboratories.”

DOD missions, accomplishments, the environment, energy security, and quality of life — all depend on leveraging R&D resources and focus while encouraging industry to partner with military installations. This work recommends that DOD coordinate with other Federal agencies and work with technology providers to develop technologies that have both a military and commercial use, and to establish a streamlined and coordinated set of “living laboratories” to demonstrate those emerging technologies.

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Acronyms and Abbreviations

Term	Spellout
AAAS	American Association for the Advancement of Science
ANSI	American National Standards Institute
ARPA	Archeological Resources Protection Act of 1979
AT&L	Acquisition, Technology & Logistics
BSR	Base Structure Report
BTU	British Thermal Unit
CBD	Chemical Biological Defense
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
COTS	commercial off-the-shelf
CRADA	Cooperative Research and Development Agreement
DARPA	Defense Advanced Research Projects Agency
DASB	Defense Space Acquisition Board
DC	District of Columbia
DDR&E	Director of Defense Research and Engineering
DLA	Defense Logistics Agency
DMEA	Defense Microelectronics Activity
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DRD	Directorate of Research and Development
DSB	U.S. Defense Science Board
DTRA	Defense Threat Reduction Agency
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EISA	U.S. Energy Independence and Security Act of 2007
EPACT	Energy Policy Act of 2005
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
FBCF	Fully Burdened Cost of Fuel
FOB	forward operating base
FPM	Feedstock Processing Module
FY	fiscal year
GDP	Gross Domestic Product
GPM	Gas Production Module
GSA	General Services Administration
HASC	House Armed Services Committee
ISO	International Organization for Standardization

Term	Spellout
JCTD	Joint Capability Technology Demonstrations
MDA	Missile Defense Agency
MEDQ	Michigan Environmental Quality
MEWEPS	Mobile Encampment Waste to Electrical Power System
NAC	National Automotive Center
NASA	National Aeronautics and Space Administration
NGA	National Geospatial Intelligence Agency
NREL	National Renewable Energy Laboratory
NSN	National Supply Number
O&M	operations and maintenance
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSD	Office of the Secretary of Defense
OT&E	operational test and evaluation
PEM	Proton Exchange Membrane
PTI	Permit To Install
PV	Photovoltaic
R&D	research and development
RDECOM	Research, Development, and Engineering Command
REF	Rapid Equipping Force
S&T	science and technology
SBIR	Small Business Innovative Research
SOCOM	U.S. Special Operations Command
SR	Special Report
STTR	Small Business Technology Transfer
TARDEC	Tank Automotive Research, Development & Engineering Center
TD	technical director
TM	Army Technical Manual
TQG	Tactical Quiet Generator
TR	Technical Report
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TUTC	Terrorism, Unconventional Threats and Capabilities
URL	Universal Resource Locator
USA	U.S. Army
USD	Under Secretary of Defense
USDOE	U.S. Department of Energy
WWW	World Wide Web

Appendix A: Technology Review Form

TECHNOLOGY REVIEW

Technology: ____

Entity:

☐ Company ☐ Academic Institution ☐ Research Laboratory

Name of Entity: ____

Address: ____

Phone: ______________________ Fax: ______________________

Email: ______________________ Website: ______________________

Point of Contact: ____

State of Incorporation (Company): __________

Patents/Intellectual Property: ____

____

Identify similar intellectual property:

____

Identify similar research and development activities:

____

____

Determine the technology's competitive advantages:

____

Years of operation (Company): ____________________

Business plan: ☐ Yes ☐ No

Target market: ____

Target market size:____

Target market trends:

____

Technology Readiness Level:

☐ TRL1 ☐ TRL2 ☐TRL3 ☐ TRL4 ☐TRL5 ☐TRL6 ☐TRL7 ☐TRL8 ☐TRL9

Ability of innovators to support commercialization efforts:

☐ High ☐Medium ☐ Low

Identify subject matter experts:

____

Abstract of Technology:

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14. ABSTRACT
The Department of Defense (DOD) has a unique opportunity to be a leader in bridging the gap between research and development (R&D) and commercial clean energy technologies. Faced with the inextricable linkage between energy, security, environment, and economics, the DOD is positioned to play an important role in the demonstration of new and emerging clean energy technologies, and also to become early first adopters of the technologies. Military installations are "living laboratories"; they offer a controlled and safe environment to demonstrate emerging technologies and to provide a critical feedback loop between the end-users and technology providers. This work reviewed Federal energy policy, explored the role of R&D in meeting DOD needs with regard to energy issues, defined measures of "Technology Readiness and Commercialization, outlined the role of installations as "living laboratories," and provided several case studies of energy-related studies done at Army installations.

15. SUBJECT TERMS
energy conservation, energy consumption, living laboratories, renewable energy

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